Mercury contents in relation to biometrics and proximal composition and nutritional levels of consumed fishes from Western Mediterranean Sea (Almeria bay).

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Abstract

The total liver and muscle mercury, and muscular composition, biometrics and trophic levels were determined in four species (*Mullus surmuletus*, *Merluccius merluccius, Auxis rochei* and *Scomber japonicus)* of Mediterranean Sea (Almeria Bay, Spain).The mercury levels did not exceed the Maximum Residue Limit, being the *M.* merluccius the one which showed the highest level in muscle. Great variations of Hg content among individuals were observed in not gregarious species. A positive correlation between Hg and trophic level or length was found in muscle but not in liver. The organ (liver or muscle) with major Hg accumulation depends on species; in *M. merluccius* was the muscle and in *S japonicus* was the liver.The results indicate that the Hg levels in fish depend on intra and inter species factors that should be taken into account in the monitory systems of Hg levels.

1. Introduction

Pollution is one of the current problems facing the environment. In this context mercury (Hg) is one of the six worst pollutants on our planet, according to the UN's International Chemical Safety Programme (Keeler et al., 2006) as it has adverse effects on most living organisms (Dietz et al., 2000), and also neurological damage, especially in children (Counter et al., 2002; Zhang and Wong, 2007). It may enter the environment from human activities, like mining and smelting processes (Gutiérrez et al., 2016; Kaitantzian et al., 2013; Odumo et al., 2014) or from fossil combustion (Kelepertzis and Argyraki, 2015; Rodriguez Martin et al., 2014; Rodríguez Martín et al., 2013). In any case, human activities have substantially raised the heavy metals levels in the last decades (Rodríguez Martín et al., 2015). The global inventory of Hg sources for the year 2000 was 2,200 ton year^{-1}(Pacyna et al., 2006). Nowadays, about 2,200–4,000 ton year^{-1} of anthropogenic Hg is emitted to the atmosphere (Kim and Kim, 1999). Coastal ecosystems are conditioned by growing anthropogenic impact. Consideration to pollution of the Mediterranean Sea is asociated to semi-enclosed sea intensification of contamination effects (Aston and Fowler, 1985). Same fish species from Atlantic Ocean contain half Hg than specimens from Mediterranean Sea (Aston and Fowler, 1985). Della Croce et al. (1997) have established that the amount of Hg discharged into the Mediterranean is 130t per year. The fish and shellfish being the food that most concern the risk associated with exposure to Hg (Zamani-Ahmadmahmoodi et al., 2014).

On the other hand, the potential health benefits related to fish consumption are due to the presence of proteins, minerals, vitamins and the presence of unsaturated essential fatty acids related (UFAs), especially omega-3 UFAs including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Nowadays the intake of fish is recommended as a healthy nutritional habit. Although people may be exposed to any form of mercury in various circumstances, diet is the mainly way of Hg accumulation (Hall et al., 1997) and seafood is one of main way exposition (OMS, 2017). The Hg content varies among fish species (Groth, 2010), feeding (Minganti et al., 2010) and length (Branco et al., 2004) or age (Monteiro and Lopes 1990; Storelli, 2005a, 2005b). The Hg is incorporated to the food chain provoking a biomagnification, increasing Hg content with trophic position, being in adult top-predator more than a million times higher than water concentration (Grigal, 2003; Ullrich et al., 2001;).

The Mediterranean Sea supplies of fish to more than 480 million people (EEA 2017), where *Mullus surmuletus*, *Merluccius merluccius, Auxis rochei* and *Scomber japonicus* are four of the most consumed species. Red mullet (*Mullus surmuletus*) is a target species of Mediterranean demersal fisheries that can be catched through different gears (Reñones et al., 1995). In Almeria Fish Market, *M. surmuletus* is located among the 20 species with highest profits in the last 3 years (328.538€ among 2015-2017, IDAPES). European hake (*Merluccius merluccius*) in one of the most importan species of the Mediterranean Sea (Chapela et al., 2007), and it's fished by longline, gillnet and bottom-trawling fishery. In Almeria Fish Market, the european hake is placed the 9th position of the most earnings in the last 3 years, with landings of 97.802 kg and 798.652 € of economic gain (2015-2017, IDAPES). Bullet tuna (*Auxis rochei*) is a fish species exploited commercially by artisanal fisheries (purse seiners, longliners and traps). Bullet tuna is the most abundant species of the tuna family in the Mediterranean, and landings in Almeria Fish

Market have been of 281.565 kg with profits of 328.955 € (2015-2017,IDAPES).The Pacific Chub Mackerel (*Scomber japonicus*) is a very important commercial species exploited by purse seiners for direct human consumption and also for can industry and as food for bluefin tuna of aquaculture. In Almeria Fish Market, chub mackerel is the second most landed species in volume (kg) of small pelagic fishes after pilchard (*Sardina pilchardus*), with landings of 722579 kg and profits of 300.072 € (2015-2017, IDAPES).

The aim of this study was to explore the potencial toxicity risk of Hg in the four species most consummed in Andalusian coast. The main goals of this work were: 1) to determine the levels of mercury contents in hepatic and muscular tissues. 2) to study the relationship between mercury content and biometric index, age, trophic level and body composition. 3) to have a first sight to the quality of fishing areas in the Bay of Almeria.

2. Materials and methods

2.1 Studied Fish species

Four popular fish species of the Mediterranean Sea with commercial importance were selected from the Bay of Almeria (Western Mediterranean Sea)

Red mullet (*M. surmuletus)* is a teleost fish of the Order Perciformes of wide distribution, is located in the Northeast Atlantic and Mediterranean, mainly in very shallow areas of the continental shelf (between 0-30m) of as much zones of rock as sand and mud (Lombarte et al., 2000; Whitehead et al., 1986). In spite of this very coastal distribution, this species can reach to inhabit depths of up to 400m, depths that the other red mullet (*M. barbatus*) does not inhabit (Lombarte et al., 2000). It is a benthic carnivore that feeds mainly on small invertebrates (crustaceans, mollusks, polychaetes) that live on or in the interior of the marine substrate (Gharbi and Ktari, 1979, Golani and Galil, 1991).

European hake (*M. merluccius)* is a demersal species teleost of the order Gadiformes widely distributed in the Atlantic Northeast and throughout the Mediterranean Sea. It inhabits from 50-750 m depth, although its most occurring habitat is in the deep zone of the continental shelf, between 150-300m (Recasens et al., 1998). *M. merluccius* is an opportunistic carnivore that feeds on adult stages of large decapods, euphausiidae and teleost fishes such as myctophids, performing daily vertical migrations to feed (Bozzano et al., 1997; Cartes et al., 2009).

Bullet tuna (*A. rochei*) is a small tuna of the Order Perciformes that is distributed by the temperate and tropical waters of the whole world, including the Mediterranean. *A. rochei* mainly feeds on zooplankton organisms, with particular preference for planktonic crustaceans such as amphipods and eufasiaceans, as well as small cephalopods, fish larvae and even adult fishes for larger bullet tuna sizes (> 35 cm) (Mostarda et al., 2007)

La The Pacific Chub Mackerel (*S. japonicus*), is a small pelagic of the Order Perciformes. It is a neritic pelagic species that is distributed mainly between 50-200m depth, in temperate and tropical waters of the northern and southern hemisphere, including the Mediterranean(Collette and Nauen, 1983) The diet of *S. japonicus* is mainly based on different stages of fishes (including cannibalism, decapods, and annelids (Castro, 1993).

2.2 Field collection

In March 2016, the four species were caught during several commercial surveys in Almeria Bay, Western Mediterranean, in the Southeast Coast of Andalusia (Figure 1). Two of the species were small pelagics fished by the purse seine vessel "El Chapu"; the Pacific Chub Mackerel (*Scomber japonicus*) in the fishing ground "La Terraila", characterised by an isobat of 100 m depth, and the Bullet tuna (*Auxis rochei*), in the fishing ground named "El Cantillo" with depths ranging between 50-180 m. The other 2 species were fished by the bottom-trawler "Jose y Fernanda", the most popular demersal species in the area, European hake (*Merluccius merluccius),* in the fishing ground "Medio Canto" near the slope, at depths 130-200m, and the abundant benthonic species Red Mullet *(Mullus surmuletus*), in the fishing ground "La Terraila", in the first 100m. The fishes were transported to the laboratory into ice for biometrics. The liver and muscle were dissected out, weighed and stored at -20ºC until lyoifilization.

2.3 Fish Biometric Indices and Body Composition

Fishes were weighted (Wt) and measured (Total length (Lt)). Age of the fishes was calculated following the formula of von Bertalanffy 's growth of other studies for each species (Table 1). Trophic level for each species was calculated through the fractioning index TROPH presented in Stergiou and Karpouzi (2001) where original studies are presented for red mullet and european hake, and from Fish base online (www.fishbase.org) for chub mackerel and bullet tuna (Table 1).This index is based in stomach contents and expresses the position of organisms within the marine food webs. The index also takes in consideration the size of the specimens

$$(1)\ TROPH_i = 1 + \sum_{j-1}^{G} \left(\mathrm{DC_{ij}} \times \mathrm{TROPH}_j\right)$$

where $\mathrm{TROPH_i}$ is the trophic level of species (i), $\mathrm{TROPH_j}$ is the trophic level of prey (j), $\mathrm{DC_{ij}}$ is the contribution of prey (j) in the diet of species (i) and G is the total number of prey. The values of the TROPH range 2.0- 4.5:

a) 2.0-2.1: Pure herbivores
b) 2.1-2.9: Omnivores with a preference for vegetable materia
c) 2.9-3.7: Omnivores with a preference for animals
d) 3.7-4.5: Carnivores with a preference for large decapods, cephalopods and fish

The mucle composition was evaluated according to the Association of Official Analytical Chemists (AOAC, 2000). Dry matter was determined gravimetrically after drying at 105±0.5ºC (DM; method #934.01) and ash was determinated after combustion at 500ºC in a mufla oven (metod #942.05) to constant weight. Content of crude protein was determined by Kjeldahl (PB; methods #954.01)(Nx6.25), and total lipid was determined by ethyl ether extraction (EE; method#920.39)

2.4 Measurement mercury levels

The total Hg in all samples was determined using a direct Hg analyzer (DMA80, atomic absorption spectrophotometer, Milestone, Wesleyan University, Middletown, CT, USA). DMA80 provides two working ranges for Hg detection: 0–40 and 40–600 ng. Each range is calibrated independently to optimise the response over the entire dynamic range. The limits of detection (LOD) and quantification (LOQ) were 0.5 and 1.25 μg kg^{-1}, respectively. The LOQ was established by the lowest calibration point; the LOD was 2.5 times lower than the LOQ when the signal-to-noise ratio was higher than 10 (Carbonell et al., 2009). The analytical procedure validation of the Hg analysis was performed with a certified reference material CRM 463 (tuna fish 2850 μg kg^{-1} DW) and ERMI-CE278 (mussel tissue 196 μg kg^{-1} DW). The Hg analysis revealed good agreement between the obtained and certified values, showing an average recovery of 97% and 101%, respectively. Results are in consonance with those of the certified values. Two replicates were analyzed per sample.

2.5 Statistical analysis

A standard statistical analysis (mean, median, standard deviation, etc.) was carried out to describe fish biometric and analytical body compositionresults. Statistically significant differences related to the control were estimated using the analysis of variance (ANOVA). Data were not transformed and significant differences between species were assessed by non-parametric Kruskal-Wallis tests (at $\alpha = 0.05$).

To study the relationship between Hg in different tissues (muscle and liver) and fish biometric (size and analytical body composition), we used CCorA (canonical correlation analyses). Discovered by Hotelling (1936), this method is used considerably in ecology (Campos-Herrera et al., 2013; Höss et al., 2011; Rodríguez Martín et al., 2014). Let Y1 and Y2 be two tables (Mercury contents, and the response variables (Y2) based on size and body composition), with variablesp and q, respectively, we obtain:

$$\rho(i) = cor(Y1a(i), Y2b(i)) = \frac{\operatorname{cov}(Y1a(i), Y2b(i))}{\operatorname{var}(Y1a(i)).\operatorname{var}(Y2b(i))} \tag{2}$$

The CCorA provide two vectors, a(i) and b(i), that are maximised. Constraints must be introduced so that the solution for a(i) and b(i) is unique. As the ultimate intention is to maximise the covariance between Y1a(i) and Y2b(i) and to minimise their respective variance. CCorA (Kianifard, 1993) provides the relationships between biological variability and sensitivity to chemical disturbance (Campos-Herrera et al., 2016; Losi et al., 2013; Takoutsing et al., 2017).The graphical results of the CCorA were presented with bi-plot scaling to evaluate the relationship. the first set of variableswere Hg contents in liver an muscle tissues and the second set of variables are the results of Fish Biometric indices and body composition parameters (Moixture, lipids, Protein, Ash, O.M. and NFE). All the statistical analyses were carried out by XLSTAT (Addinsoft Version 2012.2.02) package for Windows.

3. Results and discussion

3.1. Biomectics and muscle composition

The summary statistics (mean and standard deviation) of biometrics of fish and their age and trophic level are listed in Table 1 for the four study species. The Weight and Total Length (Lt) were similar among individuals of each species. The highest variability was found in *M. merluccius*. The *A. rochei* showed the highest values of weight and length, while the *M. surmuletus* showed the lowest ones. The estimated age indicates that the *M. merluccius*, 3.5 years old, are the oldest fishes of this study and the *M. Surmuletus* are the youngest, with one year old. *M. Merluccius* showed the highest trophic level (4.41 TROPH). On the opposite, small fishes as *M. Surmuletus* were the ones which showed a low trophic level and similar to *S. japonicus* (Table 1). The values of our species places the bullet tuna and hake with the highest TROPH levels, while the red mullet and mackerel are located in lower links corresponding to omnivores of animal preference (Stergiou and Karpouzi, 2001). The size of the individuals of each species were similar (Table 1) with a little SD because fishes were cathed in the same set of the operation gear, indicating that they were of the same school in the case of pelagic fish*, S japonicus* and *A, rochei*. Regarding demersal and benthonic species, they are not gregariouss and show more random geographic distributions, the bottom trawlers go across variable distances capturing fishes of different stocks. As larger is an individual, there are dietary changes towards larger prey, and therefore the trophic level it occupies in the marine trophic chain, this is valid both within the same species and between different species (Pauly et al. al., 1998, Pauly and Sa-a, 2000a). Body size is a good descriptor of the trophic level of a specimen, regardless of the species (Jennings et al., 2007). In addition, the age of each species must be taken into account, because their food structures grow and ingest larger prey (Deudero et al., 2004; Galván et al., 2009). Therefore, our species and the trophic values that they show, are combining both the size and the age of the specimens, and placing the hake in the highest place of the trophic chain, despite not having the greatest weight but they are the oldest fishes. Following the hake, is placed the bullet tuna, that if it has the greater weight and an intermediate age between the hake and mackerel. At lower levels are mackerel and mullet, small sizes and ages between 1-2 years (Table 1).

The study of the muscular composition is shown in Table 2. For moisture the highest value correspond to *M. surmuletus (*82,21%) and lowest in *A. rochei* (65,03%) which presents the highest percentage of lipids (23,69%) while the lower lipids content were observed in *M merluccius*. The protein is major macronutrient content in all the species analysed 66% (*A. rochei*) to 84% (*M. merluccius)*. The organic matter and NFE showed similar values among species; the lowest value was obtained in *M. merluccius* (94.67% and 5.05% respectively), and the highest in *S. japonicus* (95.52% and 9.68% respectively). The lipids percentaje observed in *A rochei* (Table 2) was sligthly higher to the one obtained by Saito and Ishihara (1996) for this species, 4.8% for dorsal muscle and 21.6% for ventral muscle, but lower than the results of Karunarathna and Attygalle (2010). *S. japonicus* showed similar lipids values to the results described by Reinitz et al. (1979), which ranged between 1.5 and 19% of the wet weight, but richer than the ones described by Celik (2008); *M. merluccius* showed aproximately double lipids levels than those published by Pérez-Villarreal and Howgate, (1987). Regarding the protein, the values obtained for *A rochei* were similar to the protein reported by Karunarathna and Attygalle, (2010), however *S. japonicus* and *M. merlucius* showed lower protein levels than the reported by Celik (2008) and Pérez-Villarreal and Howgate, (1987) respectively. In general, the values of muscular composition are in the range described by FAO (2017) for these species, nevertheless fishes are subjected to seasonal changes in body composition due to different availability and composition of their prey. Moreover, the activities of the fish such as reproduction and migration (influenced by wáter temperature and photoperiod), have an influence on the chemical composition of the fish (Bandarra et al., 1997; Olsson et al., 2003 Grigorakis et al., 2002) and it is difficult to compare data with only sampling.
A strong relation between muscle composition and fat, moisture, and weight were observed. The increase of weight is related with fat content while the hydrophobic properties of fat provoke a decrease of moisture with the increase of fat.

3.2 Mercury Fish levels

Table 3 summarises the statistics of the Hg contents in muscle and liver of the four study species expressed as dry weight (DW). In order to assess the changes in the concentration of muscle and liver the figure 2 shows the statistically significant differences between muscle and liver for each species. Hg content in muscle for *M. merluccius* fell within 555.3 - 1065.6 µg kg^{-1} (854.8±197.54 µg kg^{-1}), pointing out this species as the one with highest mercury content, with statistically significant differences with *A. rochei* (567.7±133.44 µg kg^{-1}), *M. surmuletus* (490.7±183.68 µg kg^{-1}), and *S. japonicus* (306.4±48.67 µg kg^{-1}) that showed the lowest values of mercury in the muscle (Table 3). The variations of Hg content among individual of same species should be considered to establish an adequated number of replies. A great variation of data was observed in *M. surmuletus* and *M. merluccius* while *A rochei* and *S. japonicus* didn´t show this variability. This could related with the ecology of each species; *M. surmuletus* and *M. merluccius* are not gregarious species, them there is high intraspecific variability in their feeding (Stergiou y Karpouzi, 2001) while *S. japonicus and A. rochei* live in schools and presumably with a more homogeneous diet among individuals of the school (Menard et al. 2000).

On the other hand, several studies have demonstrated elevated Hg concentrations in the Mediterranean fishes compared to the same species from other parts of the world (Harmelin-Vivien et al., 2009). The Hg level in fish varies among species and individuals of same species, and the factors that influence in the bioaccumulation are not completely known. The level of Hg in one species depends on trophic levels (Agah et al. 2006; Agusa et al. 2004; Anan et al. 2011), the size and age (AESAN 2010; Agusa et al 2004; Andersen y Depledge 1997; ATSDR 1999) and the duration and level of exposure (Authority EFS 2012).

Merluccius merluccius from Almeria bay has the highest concentration of Hg regarding the other species studied (Table 3). In the Italian coast (Brambilla et al., 2013), this species has shown mercury contents of 159 µg kg^{-1} in wet weight $^{(}$WW), slightly lower than those measured in the coast of Almeria (163 µg kg^{-1} WW). *M. merluccius* caught off the Central Adriatic (Di Lena et al., 2017) presented even lower content (85 µg kg^{-1} WW). Although, Cresson et al. (2015a) found levels of Hg in *M. Merluccius* in France mediterraneam coast from 290 to 1360 µg kg^{-1} (DW), similar to the levels of Hg analysed in this study (854.83 µg kg^{-1} DW).

In our study *Mullus surmuletus* presents a mean content of 490.7 µg kg^{-1} DM of Hg, (87 µg Hg kg^{-1} WW,) which is higher than the reported for the Gulf of Lions with 202 µg kg^{-1} DM (Harmelin-Vivien et al., 2009), for Ligurian Sea with 210 µg kg^{-1} DM (Capelli et al., 2004), but lower than the reported in the Italian coast with 258 µg kg^{-1} WW (Brambilla et al., 2013), in Central Adriatic 129 µg kg^{-1} WW (Di Lena et al., 2017), and in the Gulf of Lions with 920 µg kg^{-1} DM (Cresson et al., 2015). Also *A rochei* has presented lower levels of Hg in Almeria (198 µg kg^{-1} WW) than the reported in the Italian coast with 221 µg kg^{-1} WW (Brambilla et al., 2013) or 280 μg kg^{-1} WW (Di Lena et al., 2017). The *Scomber japonicus* species (86 μg Hg kg^{-1} WW) shows lower level than those obtained in other areas of the Mediterranean Sea, as Central Adriatic 171 μg kg^{-1} WW (Di Lena et al., 2017) or Italian coast (Brambilla et al., 2013) with 220 μg kg^{-1} WW.

In general the liver is the organ where more mercury can be found in any terrestrial or aquatic species. However, no differences in Hg levels between muscle and liver were found in *A. rochei* and *M. surmuletus* whilst the *M. merluccius* has significant higher Hg content in the muscle (854.8 μg Hg kg^{-1} DW) than in the liver (334.90 μg Hg kg-1 DW) (Figure 2). Only the *S. japonicus* showed significant higher Hg concentration in the liver 532.35 μg Hg kg-1 DW than in muscle 306.39μg Hg kg-1 DW, what means a 50% higher than in muscle (Figure 2). The liver has an important role in redistribution, detoxification and transformation of pollutants (Yamashita, et al., 2005; Maršálek et al., 2007). Havelková et al. (2008) found that the target organ to accumulate Hg depends of pollution level; the fish are from high polluted areas, the Hg accumulates in liver, in low polluted areas the target organ it is the muscle. However, in our study the fish was caught off from same area (Bay of Almeria), and the Hg content variability in the liver depends on the species (Table 3). It has been documented that species such as *Xiphias gladius* and *Thunnus thynnus* present higher Hg content in liver than in muscle (Storelli, 2005), whilst in shark it is the muscle the accumulative organ (Branco et al., 2007). However in catfish there aren´t differences in Hg content in organs, liver and muscle (Arantes et al., 2016).
The different ditribution of Hg depends on elimination rate and tranportation into de organs. The elimination and transport of Hg in *Siganus canaliculatus* was slowly distributed into muscle but was efficiently eliminated by the intestine. However the muscle didn`t eliminate the meHg. These elimination and acculumation rates seem to be specific to each species (Pen et al., 2016).

3.3 Assessing relationship between mercury content in tissues and Biometrics and muscle composition

As previously mentioned, no clear effect in the Hg accumulation have been shown when we look at each species separately. To evaluate this, CCA allows to provide the relationships between biological variability and sensitivity to chemical disturbance (Campos-Herrera et al., 2016; Losi et al., 2013; Takoutsing et al., 2017); thus, this method has been considerably used in ecology (Campos-Herrera et al., 2013; Höss et al., 2011; Rodríguez Martín et al., 2014). Numerous factors have been described that affect the accumulation of Hg. In this study the Hg content of tissues has been connected with length, weight, age, trophic level, and muscle composition (protein, lipids, ash…) showing a positive association with age and trophic level.

The CCA (Figure 3) proved the relationships between fish Biometric indices and body composition parameters versus muscle and liver Hg contents as a whole which accounted for 89% of total variance.

No association has been found between hepatic level of Hg and trophic levels, probabily due to the role in detoxification of the liver (Yamashita, et al., 2005; Maršálek et al. 2007) than that the acculation.

On the opposite, trophic level and total fish length were the factors which was most correlated with Hg contents in muscle. This correlation between trophic level and Hg muscle has been previously confirmed (Snodgrass et al., 2000) and also the size of the fish (Vieira et al., 2011; Storelli and Barone, 2013). Branco et al. (2004) found a tendency for Hg concentrations to increase with length in shark. These results indicate that the bioaccumulation of Hg is due to exposure; at higher trophic level and age, greater exposure to Hg. In the case of *M. surmuletus* the Hg levels found were higher than what it would correspond to their age and trophic level due to the fact that the habitat and feeding habits increase the exposure (Benedicto et al., 2008; Storelli et al., 2005a), for that reason red mullet is considered as species indicative of the environmental quality of the marine ecosystem (Machias and Labropoulou, 2002).

In any case, our results can be interpreted in the light of there is a great variability between species still living in the same area where have been collected, but in general, bigger species and a high trophic group tend to accumulate more mercury in the muscle tissue. By the other hand, our results indicate that hake, red mullet, bullet tuna and mackerel consumption from Almeria area does not represent a risk to health.

4. Conclusions

According the results the target organ for Hg accumulation, liver o muscle, depend on the species. The age or trophic levels are related with Hg level in muscle but not with the Hg in liver. It should be noted a high variation among individuals in non-gregarious species, *M. surmuletus* and *M. merluccius,* that indicates the area and feeding of each individual are two factors to consider in addition to age or trophic levels.

On the other hand, according to this result, the adequate and safe monitoring systems of Hg in fisheries should be designed according of the area, trophic level and gregarious habit of the species.

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Figure captions:

- Figure 1: Fishing areas for four species in Almeria Bay, Western Mediterranean Sea.

- Figure 2. Mean concentrations (±SD) of Hg on muscle and liver tissues per fish species. Footnote: Significant between tissues at * 99% ($p < 0.01$). ns. not significantly different.

- Figure 3: Ordination diagram based on the CCorA of Hg in muscle and liver tissues versus Fish Biometric indices and body composition parameters

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